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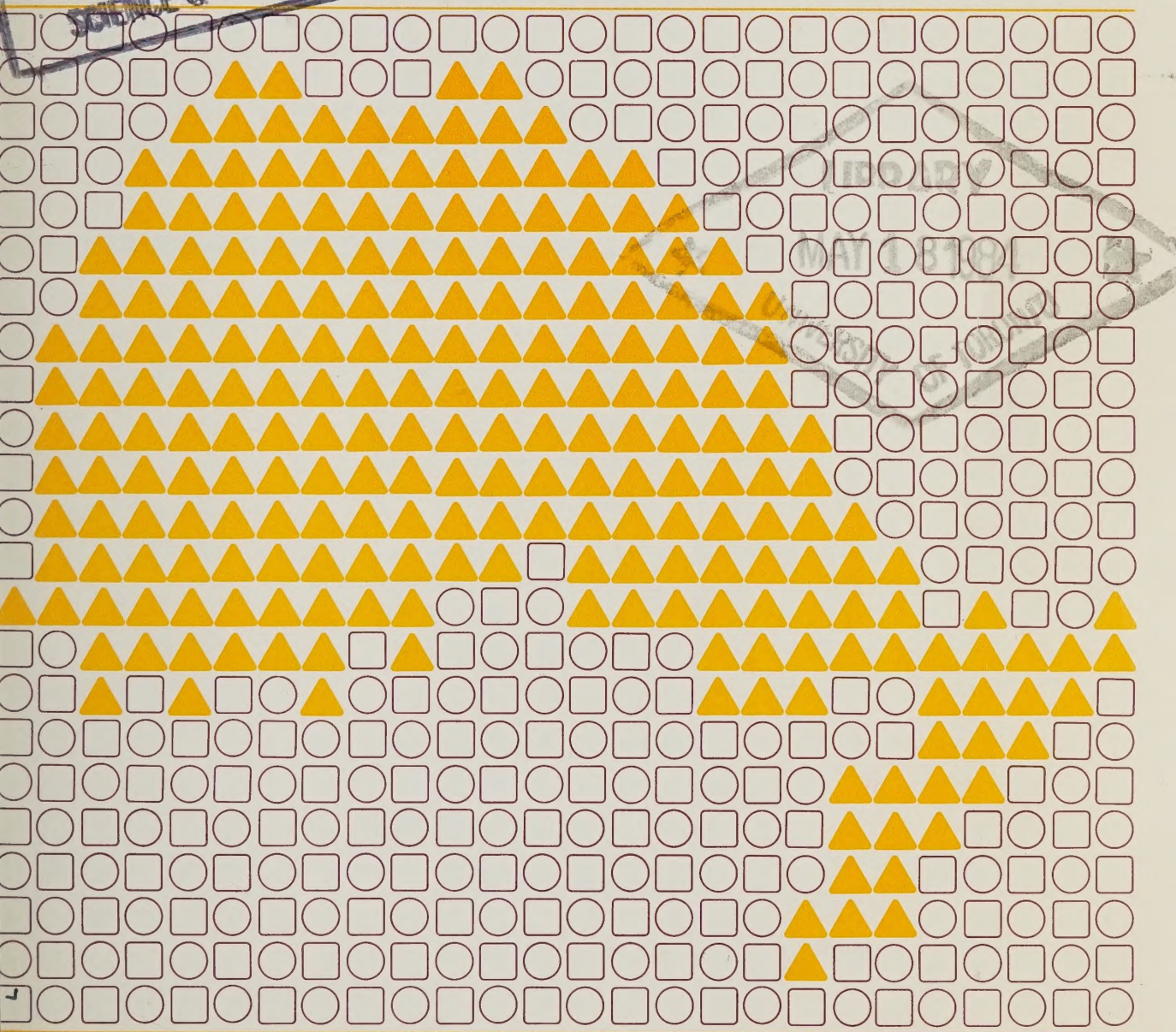
Occupational Health in Ontario

Volume 5, Number 2, April 1984

An Evaluation of Dust and Fume Conditions in Non-Ferrous Foundries in Ontario

The Effects of Ultraviolet Radiation on the Cornea

Diffusional Monitors: Usage Pattern Survey



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Occupational Health in Ontario

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3. Gamble JF, and Battigelli MC. Epidemiology. In: Clayton GD and Clayton FE. eds. Patty's industrial hygiene and toxicology. New York: McGraw Hill, 1978: Vol 1; 113-116.

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An Evaluation of Dust and Fume Conditions in Non-Ferrous Foundries in Ontario*

Summary

An industrial hygiene survey, including measurement of airborne concentrations of silica, lead, copper and zinc, was carried out for the five main job classifications in 18 non-ferrous foundries. The main causes of overexposure are discussed. The most significant source of exposure is from the cut-off saw operation. It is suggested that the occupational exposure guideline for copper fume should be applied in exposure assessment.

Introduction

To date, no comprehensive evaluation of occupational hazards associated with metal dusts and fumes in non-ferrous foundries has been published. The recent NIOSH document[1] gives three case histories, but does not include comprehensive exposure data for copper, lead, zinc and silica in all areas of the foundries. Other surveys relating to environmental hazards in ferrous foundries have been published[2-4]; some hazards, e.g. silica and binder decomposition products, are much the same as in non-ferrous foundries, but dusts and fumes of the base metals, copper, lead and zinc are peculiar to the latter.

This paper reports the results of surveys conducted in 18 out of a total of about 100 non-ferrous foundries in Ontario, the range of concentration of airborne contaminants (toxic dusts and fumes) and the measures applied to control worker exposure to these substances. The surveys included approximately 300 workers in the following main occupations:

i) moulding
ii) melting and pouring
iii) shakeout
iv) cut-off sawing
v) grinding

Process Description and Sources of Emissions

The foundry process involves the production of sand moulds into which molten metal is poured; the cooled castings are separated from the sand in the shakeout operation. Sand is recycled and finishing operations (cutting and grinding) are carried out on the castings.

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Moulding and Core Making

Because of the hazards associated with free silica the newer foundries tend to use non-silica sands, e.g. olivine, for moulding. In about two-thirds of the foundries surveyed, silica (green sand system) was still being used. The moisture content of the moulding sand was found to be between two and three per cent. Although most plants employed hand moulding, automatic moulding was also observed in about one-third of them. In all foundries surveyed, silica sand was used for core making.

Melting and Pouring

Mainly electric induction furnaces were used for the melting of metal alloy ingots, although some foundries still use gas and/or oil-fuelled furnaces. In some foundries surveyed, casting of ferrous and non-ferrous alloys, in addition to leaded-brass, is also carried out.

Molten metal is transferred in ladles that are either manually pushed along a monorail or carried by employees to the pouring line. The ladles may be covered with lids during the move from the furnace spout to the pouring lines, but generally, they are not, so the fumes rising from them are uncontrolled.

Fumes emanating from the moulds during cooling also constitute a source of worker-exposure, but the primary focus of this study was the inorganic content of dust and fumes rather than organic material from binder decomposition.

Shakeout

The cooled castings are separated from the moulds by shakeout. There is no specific location for the shakeout area within foundries; employee-exposure may therefore be a reflection of whichever occupational area is in closest proximity.

Cut-off Sawing

The cut-off saw is used to remove the sprues, gates, risers, etc. from the castings after shakeout. In the majority of foundries surveyed, cutting wheels were used, whereas band saws were used in the remainder. This operation, which is intermittent, involves exposure to metals. In addition, because the castings are only superficially cleaned prior to the removal of gates and sprues, residual sand adhering to the castings may become airborne during cutting, thereby creating a silica exposure.

Cleaning Area

A typical brass foundry has areas designated for cleaning the castings by shot blasting and/or grinding. Where the castings are cleaned by shot blasting prior to grinding, excessive silica exposure is not usually expected. In some small foundries, however, castings are not cleaned prior to grinding; shot blasting is carried out only to produce special surface effects. In such cases, exposure to silica, as well as to metals, may be anticipated.

Pedestal grinders are used for final smoothing, which is a fairly continuous operation. The number of pedestal grinders in the foundries ranged from two to 12.

Methods of Investigation

Selection

Foundries were selected at random from across Ontario, but in order to reflect the geographical concentration of the industry, the majority were chosen from within the Cambridge, Toronto, Hamilton, and Niagara regions. 'Maximum risk' employees were chosen for sampling from the moulding, furnace and pouring, shakeout, cut-off saw and grinding areas. Airborne concentrations of respirable silica (quartz) and metals (lead, copper and zinc) were measured. Since total particulate material constitutes a relatively insignificant index of toxicity, total dust was not measured.

Sampling and Analysis

1. *Silica*

The NIOSH sampling method for respirable dust[5] was modified using a 37-mm diameter 5 μ pore size silver membrane as the second-stage collector to allow direct X-ray analysis of field samples without occasioning sample loss during transfer. Minimum sampling time was usually about four hours.

For X-ray diffraction analysis, a 25-mm diameter core of the silver membrane filter was conveniently utilized. (Laboratory dust-chamber experiments have established that 50 ± 10 per cent of the sample is retained on the punched-out core). CoK_α X-rays were used in conjunction with a graphite monochromator. Diffraction peaks corresponding to the $(10\bar{1}1)$ and $(11\bar{2}2)$ atomic planes of quartz were scanned; peak height and integrated peak areas were determined, and the concentration of quartz was determined by comparison with calibrated standards. The limit of detection is 0.02 mg.

2. *Lead, Copper and Zinc*

The metal dusts and fumes were collected on 37-mm diameter, 0.8μ pore size cellulose ester filters using a closed-face three-piece filter holder. The minimum sampling time was about two hours and the flow rate was two litres per minute. The samples were digested with aqua regia[6] and analysed with a Perkin Elmer 603 atomic absorption spectrophotometer; the sensitivity of the instrument is 0.22 μg lead/ml, 0.08 μg copper/ml and 1.0 μg zinc/ml.

Results

The results for personal and area samples (silica: 191; metals: 271) are given in Table 1. These data may also be presented as a conventional lognormal probability plot[7] since industrial hygiene data are commonly found to have a lognormal distribution. On such a plot, the fifty per cent probability value represents the geometric mean value, and the ratio of the eighty-four and fifty per cent probability values represents the geometric standard deviation (GSD). As examples, data for silica (Figure 1) and lead (Figure 2) are presented in this manner.

Table 1 **Sampling Results for Silica and Metals**

Contaminant	Value	Cut-Off Saw	Grinding	Furnace and Pouring	Shakeout	Moulding and Core Making
Silica	Geometric Mean*	0.11 (0.11)	0.04 (0.04)	0.03 (0.04)	0.06 (0.04)	0.04 (0.04)
	Maximum Value*	0.83 (0.09)	0.25 (0.28)	0.28 (0.10)	0.55 (0.22)	0.28 (0.20)
	GSD	3.25	2.32	2.58	3.64	2.38
Lead	Geometric Mean*	0.18 (0.10)	0.13 (0.09)	0.09 (0.06)	0.09 (0.08)	0.06 (0.05)
	Maximum Value*	2.00 (1.08)	1.60 (0.71)	1.54 (0.84)	0.54 (0.48)	0.64 (0.33)
	GSD	4.15	4.14	3.86	3.58	3.13
Copper	Geometric Mean*	0.43 (0.23)	0.21 (0.12)	0.06 (0.04)	0.07 (0.05)	0.04 (0.03)
	Maximum Value*	4.92 (1.39)	1.96 (0.62)	0.60 (0.20)	0.73 (0.21)	0.69 (0.39)
	GSD	4.28	4.27	2.93	2.94	2.55
Zinc (Oxide)	Geometric Mean*	0.28 (0.36)	0.19 (0.18)	0.44 (0.32)	0.55 (0.53)	0.23 (0.24)
	Maximum Value*	2.61 (2.83)	3.08 (0.93)	5.35 (3.29)	3.88 (2.84)	2.30 (3.15)
	GSD	4.59	4.84	4.78	4.09	3.85

*Values in mg/m^3; values for area samples in parentheses.

The probability of overexposure with respect to the Threshold Limit Value (TLV), i.e. the occupational exposure limit (corresponding to the value of 1.0 on the 'normalized' ordinate), can be read off. The short-term

exposure limit (STEL = 0.45 mg/m^3) for lead is referred to a value of 3.0 on the ordinate. The derived results for silica and metals are given in Table 2. Copper and zinc (oxide) have different exposure limits for dust and fume[8], so, for comparison, values in Table 2 have been derived with regard to both bases.

Table 2 **Overexposure for Silica and Metals**

Occupational Area	% Samples Exceeding Occupational Exposure Limits			
	Silica	Lead	Copper*	Zinc (Oxide)*
Cut-Off Saw	54	55	70 (28)	3 (1)
Grinding	14	46	52 (14)	2 (<1)
Shakeout	35	35	17 (<1)	6 (2)
Furnace	10	35	13 (<1)	6 (2)
Moulding	15	21	4 (<1)	1 (<1)

*Values in parentheses derived using the standard for metal *dust*; otherwise, metal *fume* standard pertains.

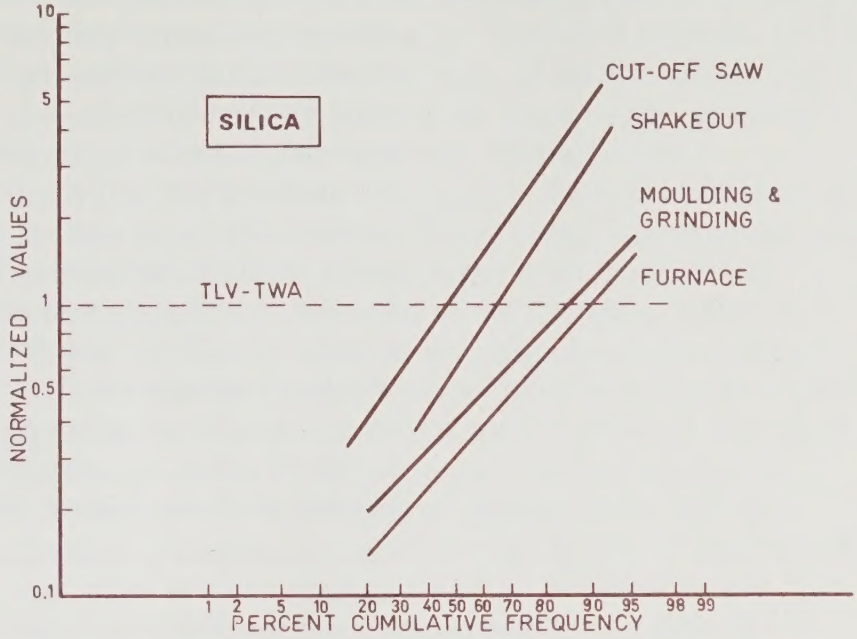
Discussion

Silica

The results in Tables 1 and 2, illustrated in Figures 1 and 2, indicate that the highest concentrations of airborne silica are generated during the operation of the cut-off saw, with about half of the samples (cf. Table 2) in excess of 0.1 mg/m^3; the subsequent order is shakeout, followed by grinding (as well as moulding and core making) and, lastly, furnace and pouring.

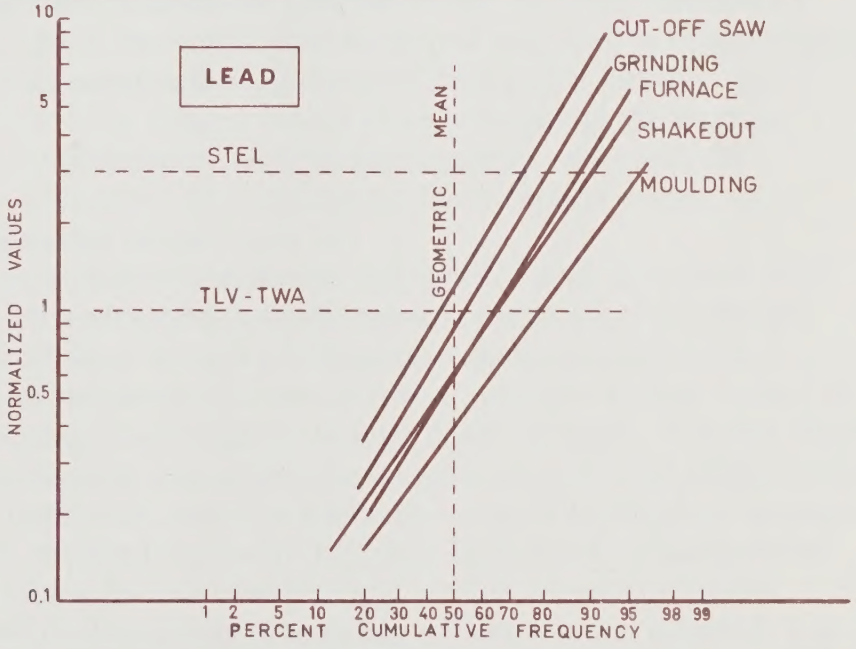
Cutting wheels are used in 14 of the foundries (band saws in the remainder) for the removal of sprues etc. from castings, and the generation of airborne silica is a result of superficial cleaning beforehand. The cut-off saw is used intermittently in most foundries and therefore actual personal exposures are lower than those indicated in Table 1. However, the fact that maximum values greater than eight times the occupational exposure limit of 0.1 mg/m^3 were obtained indicates that local exhaust at the cut-off saws is generally inadequate.

Figure 1



Silica. Lognormal probability plots for personal samples according to job classification. The concentration values (ordinate) are normalized with respect to 0.10 mg/m^3.

Figure 2



Lead. Lognormal probability plots for personal samples according to job classification. The concentration values (ordinate) are normalized with respect to 0.15 mg/m^3.

Exposure to silica is considerably less at other work stations, although high maximum values may still occur where controls are inadequate. The shakeout often has poor local ventilation and, on account of the quantity of material processed, may provide the prime contribution to the contamination of the general foundry area; area samples (Table 1) suggest that contamination tends to be fairly uniform throughout foundries. Castings are cleaned by shot blasting prior to grinding (except in some small foundries) and are therefore generally free of silica; moulding usually involves moist sand, hence these operations do not generally occasion exposure to high levels of silica. As expected, the least exposure to silica obtains with the furnace and pouring operations.

Metal

Metal contamination results from heating and abrasive processes. Zinc is the most volatile metal constituent, boiling (907°C) at or below the tapping temperature of most non-ferrous alloys (1000–1300°C). The fume consists mainly of zinc oxide and has a relatively low toxicity; its effect is not significant relative to those of lead and copper (cf. Table 2). The results for lead and copper show the same order for magnitude of exposure, viz.:
Cut-off saw > grinding > shakeout ~ furnace > moulding.

The data for the Tables and Figures refer to sampling periods of two to four hours and must therefore be modified to reflect the time basis of the exposure standards; e.g. on a 40-hr time-weighted-average basis it would be expected that the actual personal exposures would be less than those given in Table 1. On the other hand, short-term (15-minute) exposure levels must be revised upwards from those derived from Figure 2. For the cut-off saw, therefore, the short-term exposure limit of 0.45 mg/m^3 for lead would be exceeded in at least 26 per cent of the samples. The severity of exposure at the cut-off saws is exemplified by the fact that maximum values, even on a two to four-hour basis, exceed 13 times the reference standard of 0.15 mg/m^3; for the grinding operation, exposures are marginally less. These results illustrate the general lack of ventilation at the cut-off saws and grinders, perhaps reflecting a general lack of appreciation for the prominence of high exposures resulting from these operations. In accord with this view, only one-third of the saws are enclosed (although exhaust is provided in a majority of cases).

The conventional exhaust hood used at most grinding wheels has a major deficiency.[1] Fine dust particles tend to be retained in the boundary layer of air at the wheel and subsequently discharge from the front of the grinding enclosure towards the operator. Modifications incorporating auxiliary exhausts[9-11] have the potential to achieve significant (30 to 70 per cent) improvement over conventional hoods, but no instance of these design modifications was observed in the foundries surveyed. Where satisfactory exhaust operation has been achieved, conventional methods of control have been applied, albeit generally necessitating design specifications in excess of recommendations[12] for industrial ventilation practice.

It appears to be recognized industry-wide that the furnace operation can produce high levels of metal fumes, and there is more extensive control of contaminants from melting than from other operations: 80 per cent of furnaces have either mechanical or natural ventilation. The furnace hoods were found to be adequate in controlling metal fumes during the melting cycle; however, few foundries had made provision for the efficient capture of fume during transfer of molten metal from furnaces to pouring ladles. In about one-third of the cases ladles were equipped with lids to contain fume generation during transportation to the pouring line. Mobile exhaust hoods were provided at the pouring lines in about half of the foundries surveyed; the estimated effectiveness of fume capture ranged up to about 75 per cent.

The results shown in Tables 1 and 2 indicate that comparable levels of airborne metal contaminants are produced during furnace and shakeout operations. Compared with molten metal, cooled castings cannot be expected to generate significant amounts of metal fume. Similar values for area samples suggest that contamination disseminated throughout the general foundry environment may contribute a relatively high level of background contamination. Moulding sand is recycled, thereby allowing an accumulation of metal in the material, e.g. both lead and copper in concentrations up to two per cent have been determined in the fraction of used sand finer than 325 mesh.

Ventilation

Shakeout operations with mechanical ventilation were observed in approximately half of the foundries surveyed. The exhaust in these areas had a variable degree of effectiveness, as shown by the results for silica and metals in Tables 1 and 2. Housekeeping practices regarding

sand and dust also varied considerably: Dry sweeping is still often carried out. Situations in which airborne dust is generated, e.g. ineffective isolation of shakeout or undesirable work practices, may present a potential source of general contamination, particularly with regard to the metal-containing fines in the used moulding sand.

Dust and fume have markedly different compositions. Dust, from alloy, has copper as the major constituent, whereas in fume, zinc (the most volatile component) will predominate, with copper (the least volatile) as the minor constituent. It is commonly assumed that the heating processes, i.e. melting and pouring, give rise essentially to 'fumes', whereas abrasion processes generate 'dust'. Of these assumptions, the latter is less firmly held, but it remains current practice to apply 'fume TLVs' to samples taken near furnaces and pouring lines and 'dust TLVs' to samples taken at grinding, cut-off saw, shakeout, moulding and core-making areas. If it is assumed that samples taken at the furnace and pouring lines represent 100 per cent fume and that the alloy represents 100 per cent dust, the proportion of 'fume' (or 'dust') in any given sample may be determined from its copper to lead ratio according to the relationship

$$R = L_a(r_a - z)/L_f(z - r_f) = P_F/(100 - P_F)$$

where R = Fume to Dust ratio in sample
P_F = Fume content (%) of sample
r_a = Copper to Lead ratio in alloy
r_f = Copper to Lead ratio in furnace fume
z = Copper to Lead ratio in sample
L_a = Lead content (%) of alloy
L_f = Lead content (%) of furnace fume; determined in conjunction with zinc to lead ratio

Alloy compositions are variable, but the copper to lead ratio is typically between 10 and 20, usually about 16. For samples associated with the various operations, the measured values of the copper to lead ratio show a wide dispersion, but are predominantly lower than that of the alloy by an order of magnitude. The mean copper to lead ratios were as follows:

Cut-Off Saw	2.3
Grinding	1.4
Furnace	0.7
Moulding	0.7
Shakeout	0.6

This suggests a preponderance (greater than 90 per cent) of 'fume' in the samples, so 'fume TLVs' should be applied to all operations to afford a realistic assessment of *copper* hazard. In actual practice, the application of the TLV for copper fume may not affect the appraisal to a great extent since inadequacy of ventilation will generally produce concomitant elevated levels of airborne lead. In borderline situations the need for upgrading controls is no less important.

The causes of silica and metal overexposure are diverse, but they constitute, for the most part, a litany of the obvious:

- no local exhaust, enclosure or isolation of the operations, especially cut-off saw and grinding operations;
- ventilation systems poorly maintained or infrequently serviced;
- interference with natural or mechanical ventilation by draughts from open doors;
- existing exhaust systems blocked, damaged, leaking, disconnected or turned off;
- local ventilation inadequate in relation to ACGIH recommendations;
- uncontrolled spraying of silica-containing mould-release agent;
- dry sweeping carried out;
- exhaust provided, but no make-up air, giving rise to negative pressure effects;
- no lids on ladles during transportation to pouring line.

This survey reflected the conditions that obtained in 1978–9, and, for comparison, the current (1983) status is presented as well:

	1978	1983
# Foundries with Metal Overexposure Only	7	3
# Foundries with Silica Overexposure Only	1	3
# Foundries with Metal and Silica Over-exposure	8	6
# Foundries with no Overexposure	2	6

Improvements continue throughout the industry, but it is recognized that considerable delay may occur if modifications require major capital outlay, e.g. the installation of ventilation systems. It is considered, however, that most of the problems giving rise to exposure to toxic dust in non-ferrous foundries are readily recognizable and amenable to solution by conventional and generally feasible means.

Conclusions

For the five main foundry operations, silica and metal (lead and copper) exposures occur in the following order:
Silica: Cut-off Saw > Shakeout > Grinding ~ Moulding > Furnace
Metal: Cut-Off Saw > Grinding > Furnace ~ Shakeout > Moulding

The highest exposure to free silica and metals was found at the cut-off saw, with contaminant levels exceeding the respective TLVs in more than half of the samples. Lead and copper represent comparable hazards, but zinc exposure is relatively insignificant.

Consideration of the copper to lead ratios in the samples indicates that 'fumes' may predominate at all operations; it is suggested that the TLV for copper fume be used to obtain a realistic estimation of the degree of hazard for copper.

Local mechanical exhausts at cut-off saws, grinders and pouring lines were generally found to be inadequate. The most prevalent causes of silica and metal overexposure in non-ferrous foundries are either lack of local exhaust ventilation or inadequate ventilation through insufficient capacity or poor maintenance.

Résumé

Une étude sur l'hygiène industrielle comprenant la mesure des concentrations aéroportées de silice, de plomb, de cuivre et de zinc a été faite pour les cinq principales classifications d'emploi dans 18 fonderies non ferreuses. Les principales causes de surexposition font l'objet de discussions. La principale source d'exposition provient de l'exploitation de la scie à tronçonner. On suggère que les directives concernant l'exposition professionnelle aux vapeurs de cuivre devraient être appliquées dans l'évaluation de l'exposition.

Acknowledgements

The authors wish to thank the air quality technicians of the Occupational Health Branch for Air Sampling and Mr. M. Polny, Senior Air Quality Technician, for assistance in the preparation of this report.

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Sharon Thomson, H.B.Sc.

The Effects of Ultraviolet Radiation on the Cornea*

Summary

Ultraviolet radiation sources and the absorption and biological effects on the eye are reviewed. The mechanisms involved are discussed.

The harmful effects of ultraviolet (UV) radiation upon the eye have been recorded for centuries. However, their precise nature has only recently been studied. Most of the damage caused by chemical change in the human eye is associated with the 200 to 320 nm range of the electromagnetic spectrum's UV region.[1] Although both natural and man-made UV radiation may damage the eye, radiation from the sun presents a minimal hazard at the earth's surface since radiation with a wavelength shorter than 290 nm is effectively absorbed by air and water, and by ozone in the upper atmosphere.[2],[3]

A wide variety of artificial UV sources have been introduced over the last 150 years, which, together, produce radiation of wavelengths spanning the greater part of the UV spectrum.[2] Material heated to incandescence (e.g. carbon arc) results in 360 to 400 nm radiation.[4],[5] Low and high-pressure mercury lamps produce radiation in the 200 to 400 nm range, the low-pressure lamps producing radiation primarily of 254 nm.[4],[5] Xenon lamps produce a spectrum similar to that which reaches the earth's surface from the sun: Radiation less than 300 nm is minimal.[4]

Regardless of the source, the biological effects depend upon the duration of exposure and the wavelength and intensity of the radiation.[5] Abiotic effects are a result of the absorption of photons of energy by biologically important molecules. A maximum response occurs with the absorption of a specific photon of energy within a limited range.[6] For each photon of energy at a given wavelength of radiation there exists a threshold of radiation intensity, below which there are few or no abiotic effects. The absorption characteristics of biological tissues, in terms of wavelength and intensity thresholds (to produce a specific biological response), have been recently studied in attempts to discern the mechanisms associated with the harmful effects of ultraviolet radiation.

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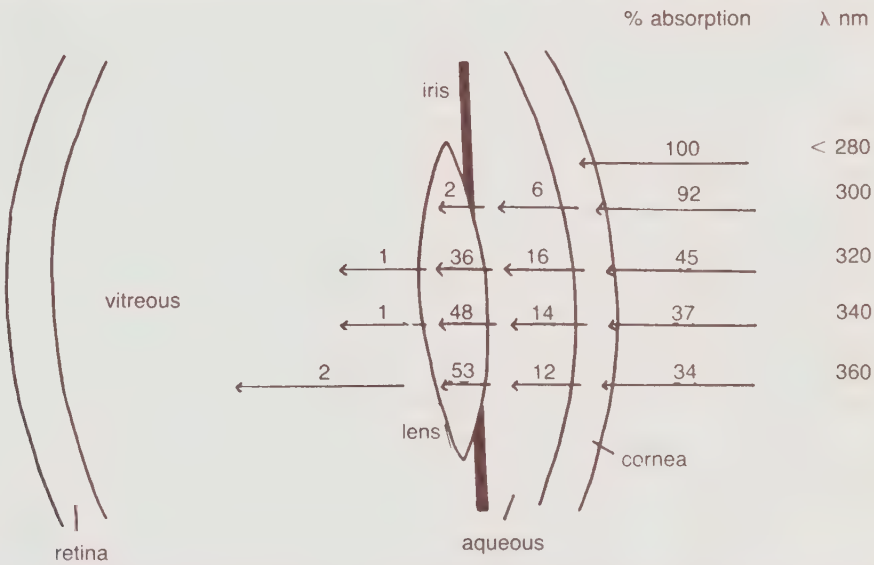
*This paper was submitted to the University of Toronto as course material for the Masters Degree in Health Science

Absorption of UV Radiation by the Cornea

The filtration of UV radiation is extremely important when considering the effects of UV on the different structures of the eye (see Figure 1).[7] The cornea absorbs approximately 100 per cent of the radiation with a wavelength of less than 285 to 295 nm.[7] As the wavelength increases, a greater percentage of the radiation is transmitted through the ocular media posterior to the cornea. The importance of this characteristic becomes evident when one recalls that radiant energy must be absorbed before a biological response can be elicited.[6] Therefore, as absorbance by the cornea increases, the threshold intensity of radiation decreases. As a result, UV radiation with a wavelength of less than 300 nm represents the greatest potential hazard to the cornea.

Figure 1



Histological Structure of the Cornea[9]

The cornea is composed of five basic layers, which, from anterior to posterior, are: the five-cell-thick epithelium, the acellular Bowman's membrane, the stroma, Descement's membrane and the single-layered endothelium.[9] At threshold levels the epithelial cells filter the UV radiation from the deeper layers of the cornea. The epithelial layer has a high rate of turnover (once every 48 hours).[8] The stroma essentially consists of keratocytes interspersed between laminae of collagen fibres. The fibre arrangement accounts for the reversible swelling properties and transparency of the cornea. The resilient nature of Descement's membrane can accommodate for the reversible swelling of the cornea. The endothelium is important for the maintenance of the structural integrity of the cornea. Its disruption leads to sudden and severe

oedema of the corneal stroma. The cornea is avascular throughout; however, there is a rich nerve supply to the epithelial layer.[1,8]

Biological Effects

Suprathreshold absorption of UV radiation results in photokeratitis and/or conjunctivitis: Inflammation of the cornea and conjunctiva respectively.[10] It has been suggested that conjunctiva involvement may be secondary to corneal damage.[2]

Usually the clinical photokeratitis is characterized by a latent period of six to 12 hours,[3,6] the length of which varies inversely with the severity of the exposure.[2,3,10] This latent period has been observed to range from 30 minutes to 24 hours.[6] The initial effect is damage or destruction of the corneal epithelial layer.[8] Granulation of the corneal epithelium can be seen, possibly due to the differential swelling and shrinking of the epithelial cells. The result is the formation of protrusions and indentations on the surface of the cornea. As cells are destroyed, a layer of dead cells builds up. Injury to the epithelium is extremely painful as numerous nerve fibres terminate here.[8] This initial epithelial reaction increases the filtration of threshold doses of UV radiation from the posterior layers.[7] If the dose of radiation is sufficiently high, stromal and endothelial damage may result.[7] Blood vessels invade the cornea, the stroma becomes cloudy,[7,8] and visual acuity is adversely affected.

Conjunctivitis immediately follows the first signs of keratitis. Often, concomitant erythema of facial skin and eyelids is observed.[10] There is a sensation of foreign bodies or 'sand' in the eyes, accompanied by varying degrees of photophobia, lacrimation and blepharospasm.[3,6,7]

The acute symptoms usually disappear after 24 to 48 hours.[10] Repeated exposure does not lead to the development of tolerance, nor is the damage usually permanent.[5,7,8] The individual is, however, visually incapacitated for varying periods of time.[3,6,10]

The Search for the Mechanisms Involved

Although photokeratitis has been noted for centuries (the term itself is somewhat more modern), the mechanism by which this reaction occurs is still unclear. The nature of the biological effects induced in the cornea have recently been experimentally studied using various artificial sources of UV radiation and a number of animals. Although earlier studies started out using rats, more recently, the rabbit has been the animal of choice.

The anatomy of the rabbit's eye is now well known, and the differences between the anterior structures of it and the human eye are minimal.[11] A 5,000-watt xenon-mercury high-pressure lamp has commonly been used to produce an incident beam of artificial UV radiation in the 200 to 350 nm range.[2,4] Following various intensities and wavelengths of irradiation the induced biological effects can be studied. Whether or not a given incident beam of radiation produces photokeratitis and/or photoconjunctivitis depends upon the threshold criteria set by the investigators. Pitts, actively researching this area, has established a list of ocular damage criteria:[11]

epithelial — discharge
— debris
— granules
— haze
— exfoliation

stromal — haze
— opacities

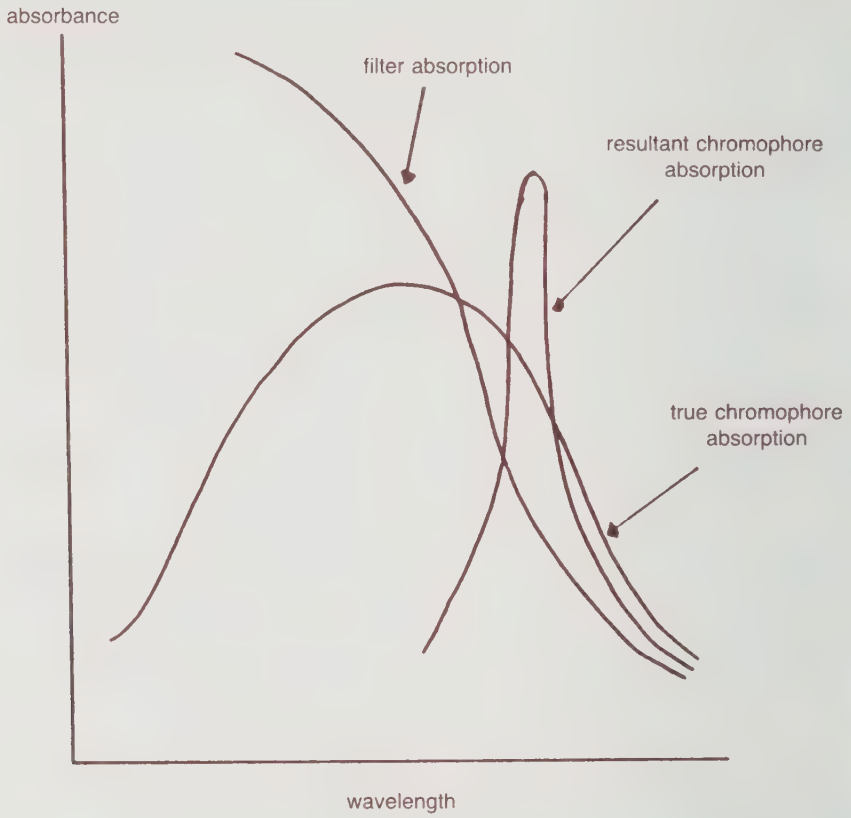
If five or more of the corneal criteria are found to be positive, then the UV-exposed eye is classified as being above threshold.[3,11]

The radiant exposure (in Jcm^{-2}) required to produce threshold effects can be determined for different wavelengths of radiation. The resultant plot of exposure versus wavelength is termed the 'action spectrum' of a specific biological effect. The action spectrum for the corneal threshold has been found to range between 210 nm to 315 nm.[4,7,11] The concept of an action spectrum does not mean that wavelengths of radiation outside this range cannot produce ocular damage at sufficiently high intensities. It indicates that the range of wavelengths within which the UV radiation produces ocular damage is high. At wavelengths outside this range extraordinary conditions must prevail for corneal damage to occur.[11]

Many attempts have been made to identify the cellular component(s) responsible for the biological effects observed on the basis of an experimentally determined action spectrum.[6] In the ideal situation, where there are no interfering factors, an action spectrum mimics the absorption spectrum of the tissue chromophores causing the biological effects.[7] However, action spectra are experimentally determined on intact animals and tissues, and a single chromophore reaction does not fully explain the observed *in vivo* response. The obtained action spectra therefore represent the cumulative effect(s) of all chromophores. They do not identify the single chromophore responsible for the specific biological effect (see Figure 2).[7] The potentially composite band shape may bear no resemblance, *in vitro*, to the true absorption

spectrum of the responsible chromophore. The true absorption maxima are usually distorted and shifted towards the red end of the electromagnetic spectrum. The identification of the chromophore, based simply on an overall action spectrum, is extremely tenuous. Although this method of investigation has severe limitations, it unfortunately has been given much attention.

Figure 2



The assumption inherent in the action-absorption spectra method is that the corneal damage is photochemical. The justification for this assumption is based upon the fact that the corneal damage is not obtained at threshold levels of radiant exposure until after a relatively long latent period, which is characteristic of photochemical reactions. If the damage was thermally induced it would become evident immediately following tissue exposure.[8],[12]

In 1946 Cogan and Kinsey provided the first reliable quantified threshold data for photokeratitis.[3] They established a threshold of 0.15 10^{-6} ergs/cm^2, at 288 nm, for the rabbit. [3,7,8] However, in the late 1970s several investigations by Pitts and associates established a threshold at 280 nm.[3,13] The evidence appears to favour the latter finding, on the grounds of reproducibility.

Despite the effort spent analysing the action spectra of photokeratitis, the identity of the critical chromophore(s) is as yet undetermined. Whether the chromophore is a protein of nucleic acid is still not known.[7] It has been well documented that amino acids are susceptible to UV damage at 280 nm, and that nucleic acids are most strongly affected at 260 nm.[7,10,11]

Cogan and Kinsey concluded that the abiotic action spectrum for the rabbit corresponds more closely to the absorption curve of albumin and globulin than it does to that of nucleic acids or nucleoproteins.[3,8] Even though their established threshold peak was situated at 288 nm, their argument cannot be ruled out. Although maximum peak locations on the globulin and abiotic spectra do not correspond precisely, they do have similar patterns.

In the late 60s and early 70s Hamerski studied the chemical changes during the post irradiation period.[7] He found that the greatest chemical changes took place during the period of maximum inflammation. As the symptoms of keratitis regressed, so, too, did the chemical changes. Hamerski arbitrarily studied the changes in sulfhydryl groups. During the latency phase of photokeratitis, free sulfhydryl and protein sulfhydryl groups gradually increased in quantity, with a concomitant increase in disulfide groups. During the same period the activity of aldaline phosphatase and acid phosphatase decreased. It was suggested that these two enzymes were deactivated as a result of cysteine sulfhydryl groups absorbing radiation, and being converted to disulfide groups. It was therefore concluded that cytoplasmic and/or nucleoproteins somehow mediate the abiotic effects observed in the cornea.[7] The conclusion that nucleoproteins are involved is in agreement with Pitts's interpretation of the abiotic action spectrum.[3],[13]

Following UV irradiation of the eye, Hamerski also noted changes in the RNA and DNA responses to histochemical tests.[7] Perhaps nucleic acids play a primary role. This cannot be discounted, even though nucleic acids absorb at 260 nm. In the wavelength region of 240 to 290 nm nucleic acids absorb 10 to 20 times as much radiation as does an equal weight of protein because all nucleic acids, unlike most amino acids, are aromatic.[8]

Regardless of what chromophores are involved (one can safely say that more than one type of biological molecule is directly affected by the incident radiation), inflammation results, but how it is caused is unknown. The cornea, as noted above, is avascular and has no tissue mast cells. One theory proposes that the changes in the chromophore result in an increased permeability of the

injured cells. Cytoplasmic contents are then 'leaked' out and act as messengers that diffuse to the vascular limbus where they signal an inflammatory reaction. How the permeability is increased has not been discovered. Changes in cellular structure and function could trigger a complex series of reactions. Sunburn reaction of the skin is also believed to be indirectly caused by a similar inflammatory process.

Conclusions

Thus far, all that has been unequivocally determined is that the action spectrum for photokeratitis ranges from 210 to 320 nm. Maximum absorption by the cornea probably occurs around the 280 nm region or perhaps at 288 nm. Attempts to match action spectra to absorption spectra of proposed chromophores has proven futile. Since the former represents the absorption of intact tissues, more than one chromophore interacts with the beam of radiation. The action spectra do not identify only those chromophores that indirectly cause photokeratitis. The role of nucleic acids and proteins cannot be determined by simple action spectra comparisons; both likely act as chromophores. In view of these difficulties, histological examination of corneal tissues at various periods of time following ultraviolet exposure are presently under investigation. It is hoped that this will shed more light on the mechanism of the inflammatory reaction.

Résumé

Les sources de radiations ultraviolettes et leurs effets biologiques et d'absorption sur l'oeil sont passés en revue et les mécanismes font l'objet de discussions.

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E. Yolanda Hanbidge,
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Diffusional Monitors: Usage Pattern Survey

Summary

A survey was sent to 270 occupational health professionals in Canada requesting information about their use of diffusional monitors. The survey revealed that, because of lack of 'government approvals', 50 per cent of the respondents were reluctant to use diffusional monitoring devices even though the majority was familiar with them and considered them to be reliable.

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Introduction

Diffusional monitors were introduced as an alternative to charcoal tubes and liquid impinger sampling methods nearly ten years ago. During this period much effort has been directed by a number of manufacturers to offer an increasing variety of diffusional methods. Today the selection includes dosimeters for ammonia, carbon monoxide, ethylene oxide, formaldehyde, hydrogen sulphide, mercury vapour, nitrogen dioxide and organic vapours.

Diffusional sampling is a convenient and simple method for collecting contaminants when evaluating industrial worker-exposure to hazardous gases and vapours.

Diffusion

In a diffusional sampling device the contaminant molecules move by *diffusion* to an adsorbent for collection. This eliminates the need for the traditional sampling pump, which mechanically aspirates air containing contaminant molecules to a solid adsorbent or absorbing solution. This molecular diffusion is a dynamic process described by Fick's Law of Diffusion, which relates the environmental contaminant concentration to the weight of material collected by the monitor, using the following equation:

$$M = D \frac{A}{L} C\ t$$

M = total mass of contaminant collected (in nanograms)
A = diffusional path area (cm^2)
L = diffusional path length (cm)
C = environmental contaminant concentration (mg/m^3)
t = sampling time

This relationship assumes that the contaminant concentration at the face of the monitor closely approximates the environmental concentration, that the monitor wall effects are negligible, and that the collection efficiency of the adsorbent element is unity.

In use the environmental concentration, C, is to be determined. The mass collected, M, is determined through

analysis and the monitoring time, t, is recorded. Therefore, a value for the DA/L term is required to solve the equation. Substitution of the appropriate units for D, A and L reduces to cm^3/sec, which defines the sampling rate for the contaminant. The sampling rate can be determined experimentally or calculated using a modified Hirschfelder equation.[1]

Once the contaminant has entered the monitor it will be retained on the adsorbent by adsorption or chemical reaction. The contaminant molecules move from the ambient atmosphere to the adsorbent because of the concentration gradient between the ambient and the adsorbent. For the sampling device to be diffusionally controlled the concentration must be zero or near zero at the adsorbent layer. Because the adsorbent has a finite capacity for the contaminant there is a limit to this criterion. When the adsorbent begins to reach its capacity the sampling process becomes controlled by the rate of adsorption and not the rate of diffusion.

Adsorption

The industrial hygienist, in his often complex environment, would like to assume that he has not exceeded the diffusional sampling limits of the monitor. It is the adsorbent's capacity that defines these limits. Therefore, the understanding of adsorption is as important as the understanding of diffusion.

Organic vapours are collected on activated carbon by physical adsorption. Often, the heat of physical adsorption is considered to be only slightly greater than the heat of condensation. Therefore, physical adsorption is viewed as a reversible process where the adsorbed molecules can readily desorb and diffuse back into the ambient atmosphere. The heat of adsorption for molecules adsorbed in the micropores (10–20 A°) of the activated carbon is much greater than the heat of condensation. In fact the heat of adsorption in the micropores is very near that associated with chemical adsorption and therefore the molecules are strongly adsorbed in the micropores.

In the industrial environment permissible exposure limits for contaminants can range from less than one ppm to 1,000 ppm. During air sampling over an eight-hour period the monitor must therefore collect from 0.05 mg to 50 mg, over three orders of magnitude. To collect a diffusionally controlled sample over this range the activated carbon must have sufficient capacity.

The adsorbent's capacity in a diffusional sampling device can be determined by spiking an excess of the contaminant onto a set of monitors and letting them stand

for 12 to 16 hours. The monitors are exposed to an atmosphere with a zero challenge of the contaminant, and the amount of contaminant lost in a given time can be determined by the removal and analysis of monitors during this period.[2] The loss of contaminant asymptotically approaches a limiting value, the adsorbent's capacity for the contaminant. The decay curve, a hyperbolic function, can be transformed into a linear relationship between the adsorbed weight and time. From the intercept, the adsorbent's capacity for the particular contaminant can be determined. Obviously, activated carbon has different capacities for various contaminants. To be useful to the industrial hygienist the capacity must be related to a physical parameter. References have been cited in the literature where the adsorbent's capacity can be related to the boiling point of the contaminant. A plot of the capacity as a function of boiling point indicates a linear relationship for the contaminants found in the industrial environment and of interest to the industrial hygienist.[1]

A comparison can then be made between the adsorbent's capacity and the amount collected during a sampling period. It can be observed that for most organic contaminants with boiling points greater than 90°C, there is sufficient capacity to collect an eight-hour sample from either a single or a multicontaminant environment. When sampling contaminants with boiling points in the range of 60 to 90°C, the amount collected during an eight-hour sampling period is near, and, in some cases, may even exceed, the capacity. Therefore, it is often recommended that the sampling period be shorter to assure that the adsorbent's capacity has not been exceeded. Of the compounds often encountered in the industrial environment, only 20 per cent have boiling points that fall within this range. High relative humidity certainly reduces the capacity, but not appreciably unless the samples are collected in environments with relative humidity in excess of 50 per cent.

Monitors for compounds other than organic vapours use what is termed chemisorption to collect and retain the contaminant molecules. The chemisorption collection media are often specific to a particular contaminant, which, when it comes in contact with the media, undergoes a chemical reaction. This chemical reaction creates a new compound, which remains in the adsorbent until analysis.

Additional information on diffusional monitoring theory can be obtained from a number of references available in the literature.[3-6]

Survey Results

A survey questionnaire was sent to 270 occupational health and safety professionals in Canada to determine the extent of awareness and usage of diffusional monitors. A 54 per cent response was obtained by the deadline. This 54 per cent is broken down as follows:

63 per cent Industrial Hygienists (Corporate)
12 per cent Consultants
11 per cent Government Health Enforcement
10 per cent Plant Safety
3 per cent Research
2 per cent Teaching

These groups represented a wide variety of industries, research organizations and government departments and services at all levels. The geographic distribution was 19 per cent from the western provinces, 56 per cent from Ontario and 22 per cent from Quebec and the Maritimes.

Approximately 90 per cent of all respondents were involved with personal and area sampling for particulates, gases and/or organic vapours. Grab samples were also used by 70 per cent. The majority of respondents (95 per cent) were familiar with the concept of diffusional monitoring, although only half had first-hand experience. This was reflected in their initial reaction to this method of sampling: Fifty per cent thought that diffusional monitoring should be evaluated and compared with another method(s); a smaller proportion (30 per cent) thought that it was a good idea, but would wait for others to prove its performance; five per cent were convinced that it could not work as well as standard methods; and the remainder expressed other opinions or did not respond.

Testing Experience

Fifty per cent of the respondents have tested diffusional monitors in the field and 19 per cent have tested them under laboratory conditions. Organic vapour monitors were by far the most frequently evaluated; others included monitors for formaldehyde, ammonia, carbon monoxide, ethylene oxide and mercury vapour.

Most field and laboratory testing was carried out simultaneously with another method. The performance of the monitors was judged acceptable in 88 per cent of field tests and 95 per cent of laboratory tests conducted. This often resulted in the incorporation of diffusional monitors into the monitoring program, although not exclusively.

In 12 per cent of field tests and five per cent of lab tests, diffusional monitors were judged to be inadequate. These conclusions were due to: poor comparisons with the reference method, limited data resulting from time constraints and/or inadequate experience and problems encountered with insufficient airflow.

NIOSH has recently drafted field performance specifications to provide criteria for estimating the usefulness of passive monitors both in the lab and under actual field conditions.[7]

Each evaluation that NIOSH cites used a different approach to the problem of field or lab testing (e.g. number of samples collected, statistical treatment of data, consideration of sampling problems peculiar to passive monitors, such as face velocity effects, etc.). As a result, it was found that the amount of information obtained and the degree of confidence associated with it was often less than desired. To overcome this problem the NIOSH documents provide a uniform testing protocol with associated evaluation criteria and recommend specific statistical analyses. By following this specific standardized procedure the industrial hygienist will obtain a better appreciation of the performance of a particular dosimeter, and will also be able to build a relevant data file that can be compared to that of other researchers.

Product Development

Question 14 of the survey asked for a list of other airborne contaminants that diffusional monitors would be useful for. The majority of respondents suggested compounds for which monitors are currently available: oxides of nitrogen, sulfur oxides, hydrogen sulfide, ammonia and chlorine. This can be interpreted either as a lack of information about the variety of diffusional monitors on the market or as dissatisfaction with the products on hand and a desire for a new or better device.

Those surveyed were also asked whether they prefer direct-reading passive dosimeters, which give time-weighted-average exposure, to monitors that require analysis. Sixty-five per cent of those who responded, answered yes, 12 per cent, no, and 23 per cent were unsure. Direct-reading dosimeters were preferred because they offer a convenient, quick assessment of workplace conditions. They provide for faster corrective action, and workers can see results for themselves. Cost and time savings because lab analysis would not be required were noted. Only a small proportion of respondents qualified a concern for the accuracy and precision of such a method.

Respondents who did not prefer, or who were unsure of their preference for, direct-reading dosimeters, lacked confidence in their accuracy and precision. Monitors that required analysis were preferred. Respondents believed them to be more accurate; could monitor more than one contaminant at a time; and offered more flexibility, such as allowing for additional analysis to be performed.

A very small proportion of respondents felt that the monitors were unreliable. Diffusional monitors were judged reliable by the majority of respondents, but half of this group was reluctant to use them unless they were approved by the government.

Discussion

A government approval would help 'justify the transition from conventional systems of pumps and tubes' and would aid in compliance with provincial legislation. Designated substance regulations in Ontario set out in the measurement codes specify methods for air sampling and analysis with provisions made for the use of alternative methods provided that the factors of accuracy and precision are demonstrated by the users to be equal to or to exceed those in the measurement codes. Furthermore, there are no legal requirements for users in Ontario to seek government approval of devices or equipment used.

Several references to traditional methods being approved by NIOSH, MSHA, OSHA and other organizations were noted among respondents' comments. Let me clarify this misconception. The NIOSH Manual of Analytical Methods is a compendium of recommended air sampling and analytical methods for the OSHA compliance programs and the NIOSH field studies. Most NIOSH methods have been validated under the joint NIOSH/OSHA Standards Completion Program to provide *accurate* personal sampling and analytical methods in monitoring for non-compliance to OSHA health standards. The program was not an attempt to designate sole procedures by which all worker-exposure monitoring must be done. Any other analytical method that an employer uses to measure employee exposure must meet the accuracy requirements set forth in the OSHA standard, i.e. +/− 25 per cent at 95 per cent confidence level if concentrations are above the standard, +/− 35 per cent if concentrations are above the action level, and up to and including the standard; or +/− 50 per cent for concentrations at or below the action level. Also to be pointed out is that the Standards Completion Program was carried out during 1974–1976 before diffusional monitors were available on the market.

OSHA, in turn, may evaluate or use passive dosimeters, but, like NIOSH, does not issue approvals.

Conclusion

The key to awareness about diffusional monitors is communication among hygienists. The majority of hygienists have learned about diffusional monitoring through published papers. Manufacturers may supply a vast amount of technical information about their products, but it comes down to performance in actual use situations that determines the applicability of a particular product. Whenever possible, this kind of information should be shared among the hygiene community.

Résumé

Une étude a été envoyée à 270 professionnels de la sante au travail du Canada pour leur demander des informations sur l'usage qu'ils font des contrôleurs de diffusion. L'étude révèle que 50 % des professionnels qui ont répondu hésitent à utiliser les systèmes de contrôle de diffusion bien que la majorité d'entre eux les connaissent bien et les estimés efficaces.

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Publications Available from the Government Book Store

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Revised Regulations of Ontario, 1980 Regulation 692/80 Industrial Establishments	$2.00
Revised Regulations of Ontario, 1980 Regulation 691/80 Construction Projects	$2.00
Revised Regulations of Ontario, 1980 Regulation 694/80 Mines and Mining Plants	$2.00
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An Occupational Health Nurse's Guide to the Preparation of a Policy and Procedure Manual	$2.00
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News and Notes

Section on Occupational Psychiatry World Psychiatric Association

The Section on Occupational Psychiatry is a relatively new section of the World Psychiatric Association. It has been developed to bring together, in an interdisciplinary form, occupational medicine and psychological medicine, and to advance international co-operation in the field of occupational psychiatry.

Occupational physicians, psychiatrists, psychologists and other social scientists will collaborate to gain new knowledge about the different influences of psychosocial and physical work conditions and environments on mental and psychosomatic health. They will also exchange existing knowledge and apply it to their work.

Some areas of occupational medicine, such as toxicology, have already been the subject of much attention; but psychosocial and psychological issues relating to the workplace also need intensive examination.

The section will co-ordinate, on a world-wide scale, the activities of its members. This should lead to increased knowledge in the field, which will be disseminated to different societal groups to promote the improvement of occupational health.

The work of the Section on Occupational Psychiatry is being carried out in the following ways:

1) By the establishment of working relations with leading research institutions as well as other organizations in the field.
2) The organization of international conferences and symposia at world congresses.
3) The international collection, exchange and dissemination of information in the field of occupational psychiatry and occupational mental health.

Membership is open to individuals actively involved in the field. Enrolment of members will be proposed by the section officers and confirmed by the WPA executive committee. Thus, Canadians who wish to become involved in the section should contact Dr. Paul Cappon, Section Committee Member of the Section on Occupational Psychiatry, P.O. Box 1749, Halifax, Nova Scotia, B3J 3A5.

International Conference on Occupational Ergonomics

The International Conference on Occupational Ergonomics will be held in Toronto, Canada, May 7–9, 1984. This is the first international ergonomics meeting that will deal exclusively with ergonomics problems in industry. This conference is aimed at research workers and practicing professionals as well as occupational users of ergonomics. It will bring together people from universities, research institutes, industry, the public sector and trade unions to share information and explore how ergonomics principles can be used effectively to optimize human performance and well-being in the workplace and to reduce occupational injury and illness.

The technical program has been structured around four types of presentations: introductory workshops (2), advance workshops (10), reviews (30) and research papers and case studies (130). All plenary sessions and reviews will have simultaneous translation in English or French. Reviews and papers will be published in the conference proceedings in the language of the author.

To obtain an advance program or for further information, please write to:

Y. Ian Noy, MASc., P.Eng.
Organizing Chairman
Toronto '84
PO Box 1085, Station B
Rexdale, Ontario
M9V 2B3
CANADA

Call for Papers

The editor of *Occupational Health in Ontario* will be pleased to consider for publication in this journal hitherto unpublished papers, by qualified professionals, on any aspect of occupational health.

When submitting manuscripts, authors should follow the instructions to contributors on the title page of this issue.

Coming Events

May 7 – 9, 1984	International Conference on Occupational Ergonomics, Harbourcastle Hilton Hotel, TORONTO, CANADA. Details from Y. Ian Noy, Organizing Chairman, Toronto '84, P.O. Box 1085, Station 'B', Rexdale, Ontario, Canada M9V 2B3. Tel. (416) 675–2235.
May 22 – 25, 1984	ARBO 84 – International Trade Fair for Safety, Health and Welfare at Work – RAI Amsterdam. Details from RAI Gebouw bv, Europaplein, 1078 GZ, Amsterdam.
July 10 – 12, 1984	Society of Occupational Medicine Annual Provincial Meeting. York, England.
August 20 – 24, 1984	Third International Conference on Indoor Air Quality and Climate – Stockholm, Sweden. Details from Mr. P.R. Warren, Building Research Station, Garston, Watford, WD2 7JR. Tel. 09273 74040.
September 9 – 14, 1984	21st International Congress on Occupational Health, Dublin, Ireland. Details from Dr. C.S. Macnamara, Organizing Secretary, XXI International Congress on Occupational Health, 44 Northumberland Road, Dublin 4, Ireland.
September 10 – 14, 1984	IXth Congress of the International Association of Agricultural Medicine and Rural Health, Christchurch, New Zealand.
September 24 – 26, 1984	4th International Congress on Industrial and Environmental Neurology. Czechoslovak Medical Society, J.E. Purkyne, Vitëzneho února 31, 120 26 PRHA 2, Czechoslovakia.
October 14 – 18, 1984	International Conference on Occupational Radiation Safety in Mining. Toronto, Ontario, Canada.
October 15 – 17, 1984	International Conference on Organic Solvent Toxicity. Stockholm, Sweden.
December 3 – 5, 1984	Inter-Noise 84 – 13th International Conference on Noise Control Engineering – Honolulu. Details from the Inter-Noise 84 Secretariat, P.O. Box 3469, Arlington Branch, Poughkeepsie, NY 12603, USA.

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ISSN 0705-9388